DIGITAL SIGNAL PROCESSING WORKSTATION

by

Dr. D. F. Lovely, BSc. PhD.
Institute of Biomedical Engineering
University of New Brunswick

Dr. P. A. Parker, BSc, MSc, PhD.
Chairman, Department of Electrical Engineering
University of New Brunswick

and

Prof. R. N. Scott, BSc, DSc.
Institute of Biomedical Engineering &
Department of Electrical Engineering
University of New Brunswick

Final Report

to

Dr. P. G. Daye, PhD.
Medical Research Fund of New Brunswick
Department of Commerce and Technology
PO Box 6000
Fredericton, NB, E3B 5H1

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1. INTRODUCTION

As stated in the original proposal, the objective of the research grant was to acquire funding for the purchase of a digital signal processing workstation. In particular a development system to fully exploit the capabilities of the Texas Instruments TMS320C25 second generation digital signal processor.

As this award was basically an equipment grant, a full detailed progress report is not applicable. However, it was thought that a brief description of the equipment purchased along with an outline of how these tools are to be employed in upcoming research was warranted. This was done in the progress report submitted to the Department of Commerce & Technology in May 1991.

However, since that report further developments have taken place within the Institute of Biomedical Engineering which involve the DSP workstation. It is the purpose of this final report to outline these ensuing projects which are now benefiting from the funding award.

2. EQUIPMENT DETAILS

As described in the progress report, the funding granted by the Medical Research Fund of New Brunswick (*90 MRF-10*) has made possible the purchase of the following items:

a) Host computer (386 running at 33MHz)

The host computer provides the platform on which the complete development system is based. A fast 386 device was chosen for this item so that software specifically tailored to the Intel 80386 processor could be accommodated. This choice also provides for some degree of long term stability in the ever changing standards of computer/software compatibility.

b) TMS320C2x SoftWare Development System (SWDS)

The SWDS consists of two parts. First, a hardware board that installs in the host computer that provides the interface between the host computer and the Analogue Interface Board (*AIB*). Secondly, the required software to setup communication with the hardware board and allow the user to write, assemble, link, load and debug TMS code.

c) Analogue Interface Board (AIB)

This external piece of hardware, provides both analog and digital input and output connections to the real world. In addition, with a TMS320C25 processor and suitable memory, the AIB can operate in a stand-alone configuration after code development has been completed. It is this part of the system which will eventually be subject to clinical trials in any application.

d) TMS320 Fixed-Point DSP assembly language tools

This software package allows for the downloading of TMS code into electrically programmable read only memory (*EPROM*), via an EPROM programmer, for stand alone operation of the AIB. Without these tools, the system is limited to using the memory on the SWDS board for program storage.

Initially, all aspects of the hardware and software were operating correctly and the development of some analogue-to-digital (*A/D*) and digital-to-analogue (*D/A*) subroutines by the principal applicant were progressing as planned. However, with the increased use of the system by students, specifically with the "***Multi-function Myoelectric Control***" project (*see below*), various faults began to appear.

Firstly, the A/D converter located on the AIB became suspect and tests by the applicant were undertaken to ascertain the exact nature of the problem. This was traced to a defective clock on the A/D subsystem which has now been replaced. In addition to this defect, the SWDS board located in the host computer, developed a fault late in 1991. This resulted in the complete board having to be returned to Texas for replacement. No reasons for the two faults can be found, although policy has been put in place to limit student access to the equipment.

Once these two set-backs were rectified, further extension of the hardware was made through the interfacing of an analogue interface circuit (*TLC32046*) to the AIB. This sophisticated subsystem provides a second method of performing both A/D and D/A functions, which can be made to appear transparent to the user.

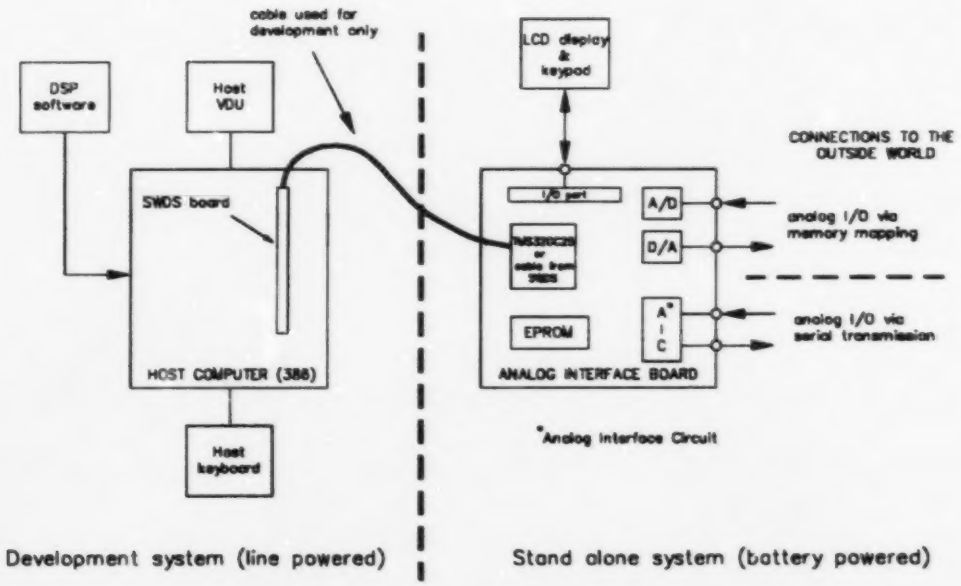

Figure 1: Hardware configuration of workstation

The above illustration summarises the final configuration of the DSP workstation. The user now has the option of two methods of communicating with the outside world, while graphical display is offered through a LCD display connected to a standard I/O port.

3. PROJECTS CURRENTLY EMPLOYING THE DSP WORKSTATION

3.1 Spinal cord monitoring

During scoliosis surgery, especially in the Harrington procedure, there is always a risk of permanent nerve cord damage. Instances of neurological complications of 1 in 100 have been quoted in the literature [1]. To reduce the possibility of this occurrence a 'wake-up' test is often performed to assess spinal cord integrity. However, there are considerable risks associated with this technique as the subject is brought partially out of anaesthesia for voluntary motor control of extremities. These risks include accidental extubation, air embolisms, laminae fractures etc.

Preliminary work carried out at the Institute of Biomedical Engineering has shown the feasibility of using evoked potential measurements as a technique to ascertain spinal cord integrity which does not require the patient to be brought out of deep anaesthesia [2]. Subsequent work, completed in 1991 [3], [4], has shown that this technique is admirably suited for implementation using a TMS320C25 processor. This work used a system which was constrained to the laboratory and was not readily exportable into a clinical environment.

Development of this system into a stand alone system is now underway due to the purchase of the DSP workstation and a subsequent operating grant from the Medical Research Fund of New Brunswick (*91 MRF-14*). Two specific areas of software development have been targeted. Firstly, an interface to a small keypad for user interaction. This is necessary for communication to the AIB without the host computer. Secondly, a liquid crystal display (*LCD*) port suitable for graphical output is similarly required.

A progress report on this aspect of the "***Spinal Cord Monitoring***" project is planned for June 1992. This has been delayed somewhat from the original proposal due to the sabaticcal leave of the principal investigator.

3.2 Adaptive noise cancellation

This is a recent project, which is closely connected with the spinal cord monitoring work. The poor signal-to-noise (*SNR*) ratio of the evoked potential signals is largely attributable to background myoelectric noise. By employing a reference channel to monitor this noise sophisticated signal processing techniques can be applied to cancel the noise in the primary signal channel. Previous work carried out in the Institute of Biomedical Engineering [5], [6] has shown the feasability of this approach but all implementations have been performed off-line using a general purpose PC type computer.

The TMS320 provides a dedicated signal processing function which should enable real time implementation of an adaptive noise cancellation scheme. Consequently, the DSP workstation is now being employed by a graduate student in an attempt to implement an adaptive noise cancellation system for use with spinal evoked potentials. In this way the SNR for the surface acquired potentials should be increase by between 5 and 10 fold. This in turn will reduce the measurement time accordingly and make a spinal integrity monitor a more acceptable monitoring instrument in clinical practice.

3.3 Multi-function myoelectric control

Recent work at UNB has seen the development of a novel approach to myoelectric control of prosthetic devices. Conventional control strategies have been based upon amplitude or level coding of the signal obtained form an active control muscle of the user. Such methods suffer from a limited number of control functions and present, for an amputee, a rather unnatural means of actuating a desired limb function.

Hudgins [7] has developed a control strategy employing an artificial neural network-based limb function classification scheme. This approach has demonstrated considerable promise in providing extended functional control of an artificial limb. Moreover, the adaptive nature of this approach yields a system which learns the appropriate limb function rather than requiring that the subject produce a contrived muscular contraction.

At present this system has been implemented using a personal computer and is not ideally suited for clinical trials. However, work is currently underway to produce a self-contained, battery powered system based on the TMS320C25 digital signal processor. Consequently, extensive use is being made of the workstation purchased through funds supplied by the Medical Research Fund of New Brunswick.

The impact of such a novel control strategy and its practical implementation can be judged by the fact that two commercial firms dealing in artificial limbs have shown considerable interest in this project. Hugh Steeper Limited (*Roehamption, England, UK*) and Liberty Mutual (*Hopkinton, Massachusetts, USA*) have both contributed considerable financial support for this project over the past three years.

4. SUMMARY

In summary, the DSP workstation is now installed in the Institute of Biomedical Engineering and is presently being used by one faculty member, two staff members and one graduate student. All features of the system are now fully operational, with the option of using A/D and D/A functions either serially via an analogue interface circuit or via parallel interfaced A/D and D/A converters. In addition, the purchase of this development system is already impacting on several projects within the Institute of Biomedical Engineering, moving the results of academic research further towards practical reality.

5. REFERENCES

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